Automatic Specialization of Modular Robot Limbs

Completed Technology Project (2016 - 2020)

Project Introduction

Modular robotic systems have the potential to be adapted to varying tasks using a single platform and enable customizable robots to be developed faster and more economically than conventional robots. Currently, no practical modular robots exist, and even the best engineering experience, calculations, and intuition do not reveal how to effectively configure (arrange module type and order) and program them. My research goal is to develop the underlying mathematics of module configuration, and develop the technology to automate the design and programming of modular robotic structures. Given a set of well characterized modular parts, it should be possible to find an optimal configuration to solve a task. However, key functions (for example, the degree of dexterity in a desired region of space) cannot be optimized analytically, so a computationally expensive search must be done over a large number of configurations. I seek to discover the paths towards the optimal configuration by determining the systematic ways in which incremental continuous or discrete changes in configuration affect a limb's motion. Even with such pathway information to speed up the search, there will be many nearly optimal solutions. To address this challenge I plan to take inspiration from biology, which has examples of how modularity served successful adaptable in animals, like insects and other arthropods. It is thought that the relative simplicity in adaptation achieved through body part segmentation is responsible for rapid evolutionary diversification. Based on the hypothesis that evolution has served as a selection and search process, I will use common limb features converged upon by evolution, like segment length, joint orientation, and reachable regions, as a basis set for similar robotic limbs. I will use these basis features as starting points and weighting factors in the configuration optimization, with the goal of create a more computationally efficient approach to designing modular robot limbs. Optimally configured modular manipulators would have many space applications. Over the course of extended space travel or extraplanetary missions, many repair, hazardous tasks, construction, or repeated manual labor would be well-suited for robotic assistance, with each task most effectively accomplished by a specially configured robot. Modular robots can provide reconfigurability without requiring a specialist or extra hardware, such that it would be possible to achieve a wide variety of functions with a single platform and less mass than multiple robots. Additionally, an optimally designed modular manipulator would be more effective and require fewer redundant components than would a generic manipulator, and one could easily reconfigure its joints, links, or functional tool to respond to a change in task. Results from this project could have a number of broader impacts in manufacturing, legged search and rescue, mobile manipulation, or other domains requiring adaptable robots. I hope that my plan to find more efficient approaches to design robot limbs will result in methods useful for future robot manipulation, legged locomotion, and modularity research.

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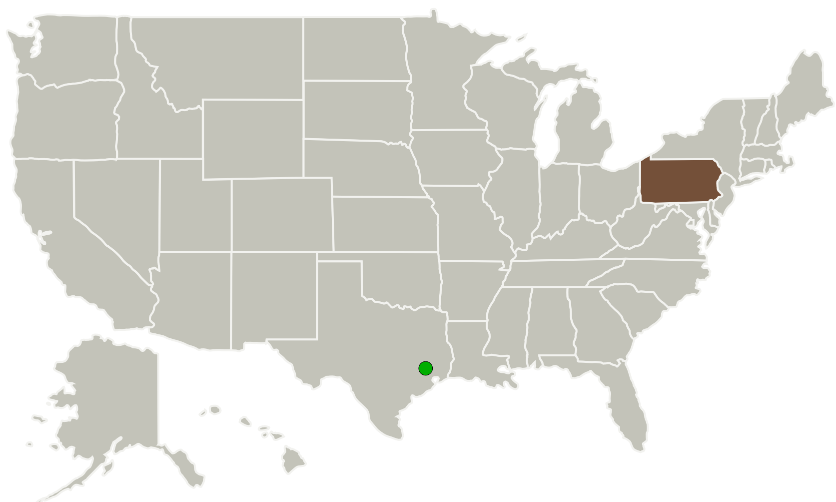
Anticipated Benefits

Modular robots can provide reconfigurability without requiring a specialist or extra hardware, such that it would be possible to achieve a wide variety of functions with a single platform and less mass than multiple robots. Additionally, an optimally designed modular manipulator would be more effective and require fewer redundant components than would a generic manipulator, and one could easily reconfigure its joints, links, or functional tool to respond to a change in task. Results from this project could have a number of broader impacts in manufacturing, legged search and rescue, mobile manipulation, or other domains requiring adaptable robots.

Primary U.S. Work Locations and Key Partners



Organizations Performing Work	Role	Type	Location
Carnegie Mellon University	Lead Organization	Academia	Pittsburgh, Pennsylvania
Johnson Space Center(JSC)	Supporting Organization	NASA Center	Houston, Texas

Primary U.S. Work Locations
Pennsylvania

Organizational Responsibility

Responsible Mission Directorate:

Space Technology Mission Directorate (STMD)

Lead Organization:

Carnegie Mellon University

Responsible Program:

Space Technology Research Grants

Project Management

Program Director:

Claudia M Meyer

Program Manager:

Hung D Nguyen

Principal Investigator:

Howard Choset

Co-Investigator:

Julian S Whitman

Project Website:

https://www.nasa.gov/strg#.VQb6T0jJzyE

Technology Maturity (TRL)

Start: **2**
Current: **2**
Estimated End: **3**

1 2 3 4 5 6 7 8 9

Applied Research | Development | Demo & Test

Technology Areas

Primary:

- TX04 Robotic Systems
  └ TX04.6 Robotics Integration
    └ TX04.6.1 Modularity, Commonality, and Interfaces

Target Destinations

Earth, The Moon, Mars